# Appendix I
# Changes in Canadian Deuterium Uranium Reactor Operations

Ontario Hydro operates 20 Canadian Deuterium Uranium (CANDU) reactors capable of using mixed oxide (MOX) at five nuclear generating stations in the Province of Ontario. Eight of these units are located at the Bruce-A and Bruce-B Nuclear Generating Stations, a 930-hectare (2,300-acre) site on Lake Huron about 300 kilometers (186 miles) northeast of Detroit, Michigan. The Bruce-A Nuclear Generating Station, which contains four 769-megawatt electric reactors, a common powerhouse with four turbine generators, a heavy water plant, a process steam transformer plant, a central services area, pumphouses, standby generators, and other support facilities, is used as the reference site for the disposition alternative evaluation. One or up to four of these units could be used for Plutonium (Pu) disposition for this alternative. The reference reactor MOX fuel cycle, adapting the standard CANDU fuel bundle in the four reactors, would dispose of approximately 2 metric tons/year (t/yr) of Pu (2.2 short tons [tons]/yr) and eliminate the mining and refining of approximately 6,000 t/yr (6,600 tons/yr) of uranium ore. The use of the CANDU reactors would be subject to the approval, policies, and regulations of the Canadian Federal and Provincial Governments. The fuel cycle is depicted in Figure I–1.

An alternate fuel bundle design using uranium fuel (the CANFLEX fuel bundle), which is currently undergoing reactor qualification, might be used. This fuel bundle has smaller diameter elements in the outer rings that would operate at a lower linear power rating, permitting higher Pu concentrations. Both designs have essentially the same Pu disposition capacity. The design is expected to reduce the number of fuel bundles and waste volumes by half.

The Bruce-A Nuclear Generating Station was selected as the reference plant for the following reasons:

- The reactor is designed without thermal neutron absorbing control rods to flatten power distribution in the central region of the core, a desirable attribute relative to thermal power margins. MOX fuel would perform in the same manner as natural uranium fuel in flattening the power distribution.

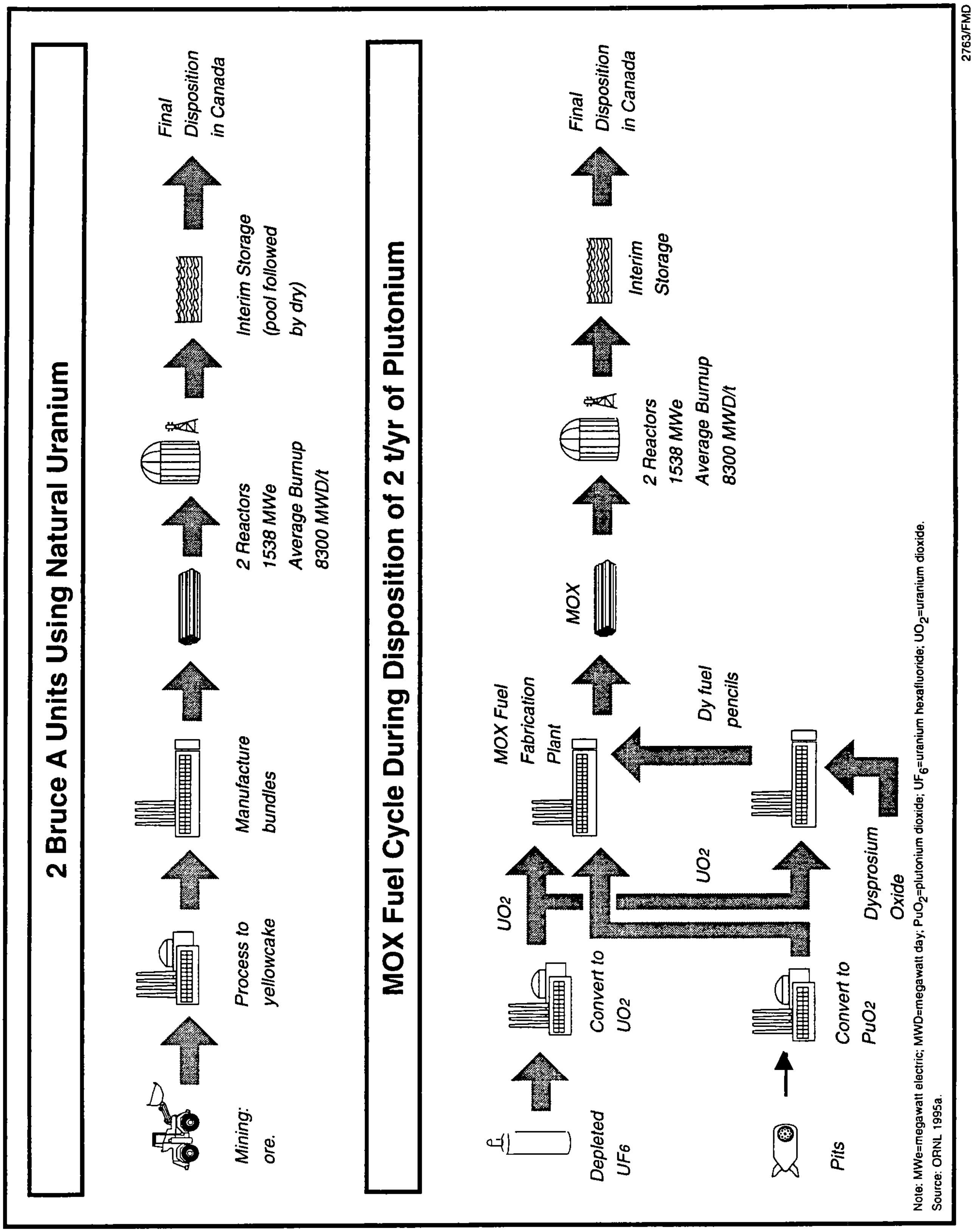
- The site is a base-load station that will maximize fuel consumption since reactors operate continually at or near their full load capability.

- The site is remote from population centers, yet relatively close to U.S.-Canadian border crossings for the shipment of MOX fuel from the United States.

- The site has current International Atomic Energy Agency approved safeguards and a Perimeter Intrusion Detection and Assessment System.

**Reactor.** Instead of a single large pressure vessel, the reference CANDU reactor has a horizontal, cylindrical, heavy water-filled, calandria tank containing 480 fuel channel assemblies (also referred to as tubes) and reactivity control units. Replacement of these tubes, "retubing," corresponds to core replacement in other reactors. The heavy water is the neutron moderator and reflector. This entire assembly is contained in the light water-filled shield tank to form an integral structure that provides operational and shutdown shielding.

Each fuel channel assembly consists of a zirconium-niobium alloy pressure tube contained within a zircaloy-2 calandria tube that provides a gas-filled, thermally insulated annulus separating the high pressure and high temperature heavy water coolant in the pressure tube from the low pressure and low temperature heavy water moderator in the calandria. Reactor neutron and gamma flux is attenuated through a latched steel shield plug mechanism inside the end fitting.




Note: MWe=megawatt electric; MWD=megawatt day; $PuO_2$=plutonium dioxide; $UF_6$=uranium hexafluoride; $UO_2$=uranium dioxide.
Source: ORNL 1995a.

**Figure I–1. Mixed Oxide Fuel Cycle.**

Heat is removed by circulating heavy water coolant from the fuel channels to the steam generator, where it is transferred to the light water side. This system includes circulating pumps, headers, feeder pipes, the primary side of the steam generators, and preheaters. During operation, pressure is maintained by steam bleed valves connected to the pressurizer and immersion heaters within the pressurizer vessel.

The heavy water moderator circulates through the calandria and is cooled by heat exchangers. Moderator chemistry is maintained by the ion-exchange columns of the moderator purification circuit. Helium is the moderator cover gas.

Fourteen compartments within the reactor function as light water zone control units. These zones contain volumes of water, which are used to control reactor power. Self-powered, in-core neutron flux detectors located in each zone, along with channel thermal measurements, are used for power measurements by the reactor control system. On-power refueling and soluble neutron-absorbing material in the heavy water provide long-term reactivity control.

Steam from the secondary side of the steam generators is transferred to steam drums where it is routed to turbine generators. The turbines are tandem-compound, single-shaft machines that drive electrical generators. Each turbine has a double-flow, high-pressure chamber that discharges to a steam reheater that raises steam temperature for three double-flow, low- pressure chambers.

**Fuel Handling and Storage.** CANDU reactors can be refueled on-line. Operator consoles remotely control the fueling operation. A fueling duct traversed by two sets of transport trolley rails is used to move fresh MOX fuel to each reactor. In their loading area, new fuel bundles are placed in fueling machines that then pass through the containment wall port to fueling machine heads. At the reactor, the loading head is aligned with, and locks onto, the selected fuel channel end fitting. The loading head inserts new fuel bundles two at a time. At the other end of that channel, fuel bundles are displaced into a spent fuel head. After the required number of bundles has been placed in the channel the loading head is unlocked. This procedure is repeated until the designated channels are fueled. The irradiated fuel is discharged to the primary irradiated fuel storage bay. The spent fuel is stored here for a minimum of 6 months before it is transferred to the secondary irradiated fuel storage bay. The primary irradiated fuel storage bay can store 4 reactor years of fuel at an 80-percent capacity factor, while the storage capacity of the secondary bay is approximately 64 reactor years.

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